A Study of Debinding Behavior and Microstructural Development of Sintered Al-Cu-Sn Alloy

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Abstract.

A new method has been developed to fabricate microcomponents by a combination of photolithography and sintering of metallic powder mixtures, without the need for compression and the addition of Mg. This involves (1) the fabrication of a micromould, (2) mould filling of the powder/binder mixture, (3) debinding and (3) sintering. The starting powdered materials consisted of a mixture of aluminium powder(average size of 2.5 um) and alloying elemental powder of Cu and Sn(less than 70nm), at appropriate proportions to achieve nominal compositions of Al-6wt%Cu, Al-6wt%Cu-3wt%Sn. This paper presents detailed investigation of debinding behaviour and microstructural development.

Keywords: micron-sized aluminium powder, nano-sized alloying powder, thermogravimetric analysis (TGA), differential scanning calorimetry (DSC), X-ray diffractrometry (XRD)

1. Introduction

Aluminium alloys are widely used in many engineering applications due to its unique features of lightweight and high strength properties. Metallic injection moulding (MIM) technology has been successful in making precision components out of metallic powders. However, MIM is known to undergo severe dimensional change after sintering. Furthermore, aluminium powder is known in the powder metallurgy area to be the most difficult material for sintering, because the surfaces of powder particle are covered by tenacious oxide layers that cannot be broken or removed by heating[1-2] due to the thermodynamic stability of the oxide. To achieve an unstable oxide layer and to reduce its thickness, it requires a dew point below -140°C[3] or an oxygen partial pressure of less than 10-50 atm at 600°C[4]. However, these conditions can not easy to obtain.

In general, in aluminium powder metallurgy, the powder is compressed in a container to cause the oxidized surface layers to rupture, which in turn induces deoxidisation by adding Mg in the aluminium as prealloyed or blended mixture of powder to improve sinterability[5-7]. In aluminium powder metallurgy, Cu and Sn is commonly used as alloying additions for strengthening and enhancing sinterability of aluminium powders. Although such methods are effective, it is difficult to implement them in some aluminium prototyping and especially in the fabrication of microcomponents, for example, where soft moulds are used and the miniaturization requires the use of ultrafine or nano-sized metal powder.

Currently, there are only few studies on the sintering of loosely packed metal powders of sizes ranging from nanometer to few micrometers. This paper presents preliminary studies on the effect of addition of binder, nano-sized powder of Cu and Sn on the sintering of loosely packed micron-sized Al powder together with debinding behavior.

2. Experimental and Results

Micro-sized Al(mean size 2.5µm), nano-sized Cu and Sn powders(less than 70nm) are used in this experiment. Al-6wt%Cu and Al-6wt%Cu-3wt%Sn with overall sample weight of 3 gram were prepared. Ethanol was then added to this mixture to prevent the airborne. The mixing was done for 2 hours by using a magnetic stirrer. After sufficient mixing, the mixture was dried.

80wt% of Al powder, 5wt% of nano-sized Cu powder and 15wt% of adhesive with acetone were mixed as a slurry and dried.

In order to study the effect of adding nano-sized Cu and Sn on the sintering of Al powder, a control sample was prepared from pure elemental Al powder.

Table. 1. List of sintering conditions used in this tudy.

Sample	Binder	Sintering Temperature	Sintering Time	Atmosphere
Pure Al	No	630°C	2 hr	Ar
Al-6wt%Cu	No	600°C	1hr, 11hr	N2
Al-6wt%Cu-3wt%Sn	No	600°C	1hr, 11hr	Ar and N2
Al-5wt%Cu-15wt%Adhseive	Yes	600°C	1hr, 11hr	Ar

Sintering of samples was performed using a Carbolite tube furnace maintained at temperatures between 630°C and 600°C for up to 11 hours for pure Al and Al alloy mixture powders, respectively, in a dynamic flow of either Ar or N2 gas. Table 1 shows the list of sintering conditions used in this study.

To understand the high temperature behavior of the Al, Cu, powders and binder mixture, thermal analysis was performed by STA. We found that over 90% of the binder weight evaporated during the temperature ramping up to 450°C in Ar-gas.

This evaporation of binder makes the sintering process simpler as no additional debinding process is required. That is, the binder becomes evaporated in-situ during sintering cycle inside the furnace.

Among the various conditions for sintering, the best powder mixing ratio is Al-6wt%Cu mixture. Therefore, this mixture was used with adhesive binder. An adhesive binder was introduced into the powder mixture in order to increase the bonding strength of green structures. Al-6wt%Cu powder mixture was used to analayze the effect of adding adhesive binder on sintering of loosely packed Al powders. The powder mixture with binder was then sintered at 600˚C for 11hr at Ar atmosphere. Fig. 1 shows sintered mictostructure of this sample. The microstructure consists of Al2Cu intermetallic in Al matrix.

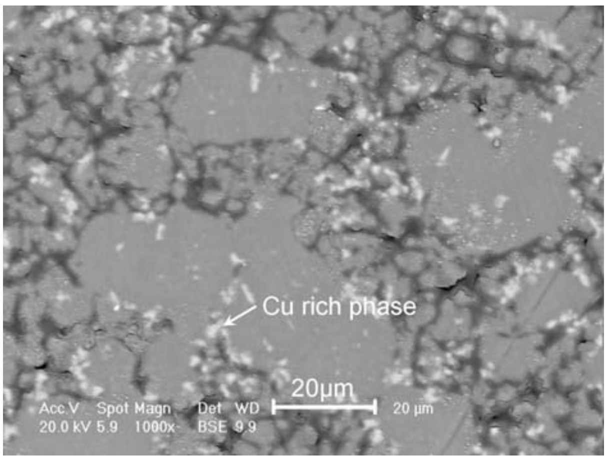

Fig. 1. The sintered microstructures of Al-5wt%Cu-15wt%adhesive binder at 600˚C in Ar, for 11hr.

3. Summary

Loosely packed Al alloy powder sintering was studied in different composition, sintering time and atmosphere with and without adhesive binder.

Based on our findings, the following conclusions can be summarized as:

1. The sinterability of Al-6wt%Cu and Al-6wt%Cu-3wt%Sn mixtures were investigated and processing optimum conditions were proposed.
2. Sintering process was simplified by using adhesive binder system.
3. Loosely packed Al-5wt%Cu-15wt% binder mixture was successfully sintered.
4. The microstructure of sintered Al-5wt%Cu-15wt% binder powder mixture consisted of Al2Cu intermetallic in Al matrix.

4. References

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